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TECHNICAL MEMORANDUM No. 8/M/68

Comparative Stress Relaxation Tests for Two Grades of Polytetrafluoroethylene

B.L. Hammant

J. Roberts

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by

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Reference: [illegible]/191/018

1. SUMMARY

The mechanical relaxation stiffness of two grades of polytetrafluoroethylene (PTFE) are compared using the ERDE stress relaxation test. The materials are an unfilled PTFE and a filled PTFE.

For short loading times the filled PTFE is found to be the stiffer material, but in the long term the unfilled PTFE has a better performance.

2. THE ERDE STRESS RELAXATION TEST

Since a detailed description of the apparatus (1) has already been given it is only necessary to mention the principle of operation.

As shown in Fig. 1 the apparatus measures the rigidity or stiffness of a beam after it has been bent around a former for a given period of time. This is a relaxation test in which the load required to keep the beam bent to the fixed deformation decreases with time.

In the first stage of the test the beam is very rapidly bent against the former by means of the ballistic pendulum carriage and magnet. After the beam has stress relaxed in the fixed position for a given period of time the magnet current is switched off and the pendulum is thrown to its maximum displacement position. This maximum displacement can be measured using a linear variable displacement transformer with a pen recorder. A much simpler recording method is the mechanical device in which a marked untwisted cord, carried in a graduated glass tube, is permanently displaced by the pendulum. This method is the basis for a relatively inexpensive commercial scientific instrument manufactured by A. Macklow Smith Ltd., Camberley, which can be used for a number of tests such as softness, consistency and resilience at any required temperature from ambient to 200°C.

Denoting the maximum pendulum displacement by D_2 and relaxation stiffness at any time, t, by E_t, then a first approximation (1) for comparative purposes is:-

$$E_t = 12mgR^2(D_2^2 - D_1^2)/bd^3La \qquad \ldots 1$$

where m is the mass of the pendulum carriage, R the radius of the former, D_1 the distance the pendulum is initially drawn to the magnet, b and d the breadth and depth of the beam, 2a the distance between loading points, and L the length of the ballistic pendulum supports.

Values of E_t calculated from the experimental values of D_2 are then plotted against the time, t, for which the beam is bent. It is preferable to plot log t instead of t to include as wide a time scale as possible. For similar reasons a log E_t scale is required when comparing materials covering a wide range of stiffnesses.

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The flexural mode is chosen because it is of considerable practical interest and a relaxation experiment is preferred to creep because it is easier to maintain a constant deformation than constant stress.

3. RELAXATION DATA

The test materials (an unfilled and a filled PTFE), were supplied by H. Crossley (Packings) Ltd., Bolton who asked for the comparative tests described to be carried out.

The relaxation data obtained for both grades of PTFE at 22°C is shown in Fig. 2 as plots of E_t against log t. The experimental points shown are the mean values of results taken when the beam is bent first in one direction and then in the reverse direction. This was found to be necessary due to some distortion in the samples from which the beams were cut.

It is seen that for short loading times the filled PTFE is the stiffer material. However as the loading time is increased the stiffness of the filled PTFE decreases more rapidly than the unfilled PTFE.

It has been found (1) that relaxation data can be described using the empirical equation:

$$(1/E_t) = A + B\tanh\,[C(\log t) + D] \qquad \ldots\ \underline{2}$$

The values of the empirical constants required in Equation 2 for each material are given in Table 1 and the curves derived shown in Fig. 2. For comparison, data for a low density (0.92 g/cm^3) polyethylene is also shown in Fig. 2.

TABLE 1

Material	Equation Constants				Equilibrium Modulus E_∞	
	A $\times 10^9$ $m^2 N^{-1}$ [redacted]	B $\times 10^9$ $m^2 N^{-1}$ [redacted]	C	D	$N\,m^{-2}$ $\times 10^{-8}$	psi $\times 10^{-5}$
Unfilled PTFE	2.539	2.521	0.1907	-0.958	1.976	0.287
Filled PTFE	3.529	3.505	0.1843	-3.484	1.422	0.206
Polyethylene (Low Density)	22.24	21.59	0.298	-2.984	0.228	0.033

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The limiting modulus, E_∞, for an infinitely long loading time is equal to $1/(A + B)$. This minimum stiffness of the material is termed its equilibrium relaxation modulus. It is a design limit in that the reactive load of the component would remain unchanged for an infinite time. This minimum modulus can also be taken as a measure of the softness of the material for the temperature at which it is measured.

From the derived curves of Fig. 2 it is seen that for loads applied over periods of time greater than 10^4 s, the filled PTFE is the less rigid material. This would not be appreciated from tests carried out only over the conventional loading time range of 15 to 45 s.

If the present relaxation data need to be compared with dynamic data the dynamic frequencies, f (Hz), are converted to equivalent relaxation times $1/2\Pi f$ [1.592 dHz] (2).

4. CONCLUSIONS

It has been shown that when a filled PTFE, and an unfilled PTFE are subjected to a constant deformation for various periods of time, the stiffness decreases with time.

Over the conventional loading time range of 15 to 45 s the filled PTFE is the more rigid material, but for long periods of deformation it is less rigid than the unfilled PTFE. In addition the rate at which stiffness, E_t, decreases with time is greater with the filled PTFE.

The minimum relaxation modulus at infinite time is a design factor which enables a component to be constructed to support a given load for an infinite loading time. In this respect unfilled PTFE has a marginal advantage. This aspect cannot be appreciated using conventional mechanical tests.

5. REFERENCES

1. Hammant, B.L. and Roberts, J., ERDE Report No. 14/R/68.

2. Williams, M.L., 1964, A.I.A.A. J., 2, 5, 785.

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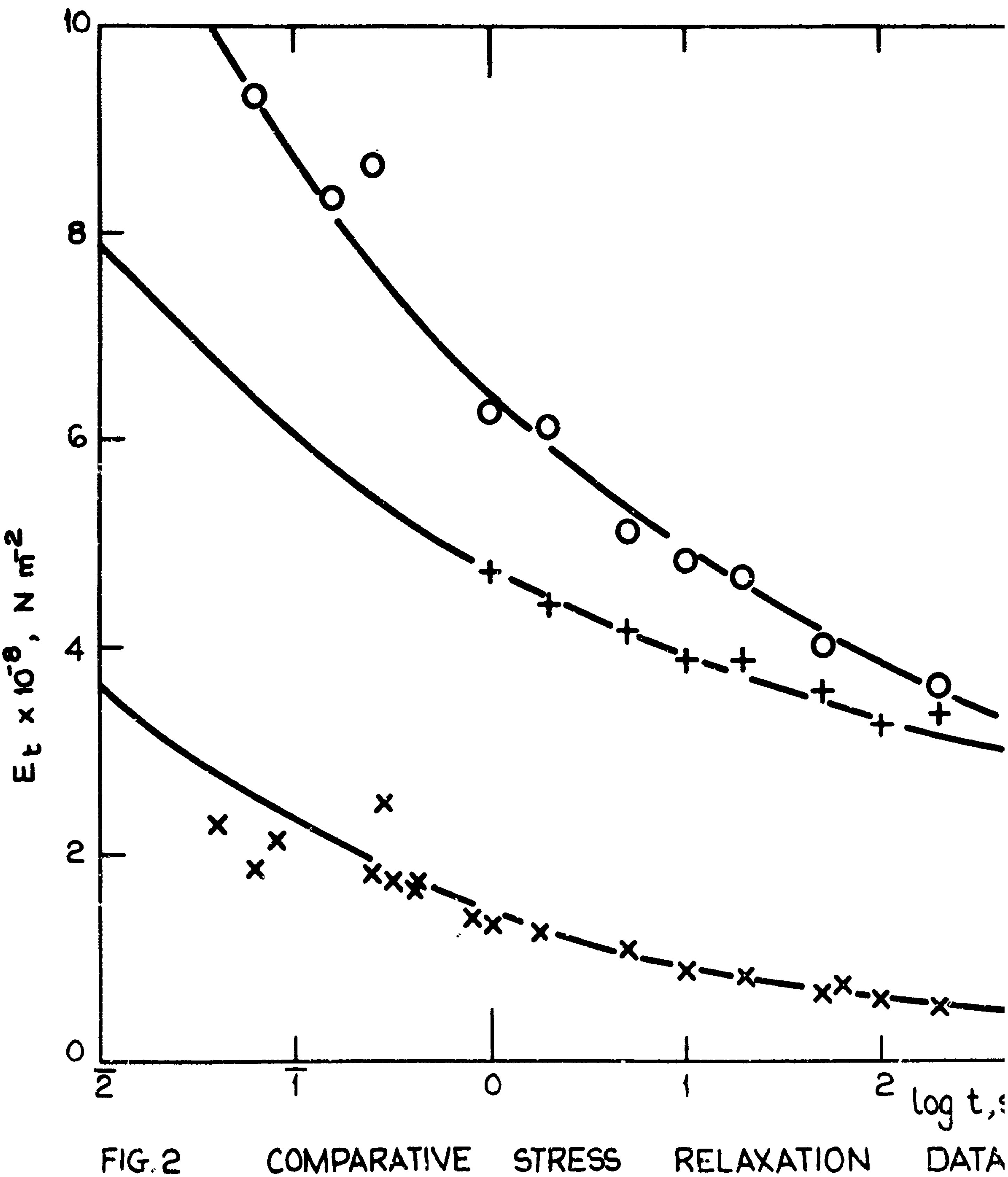
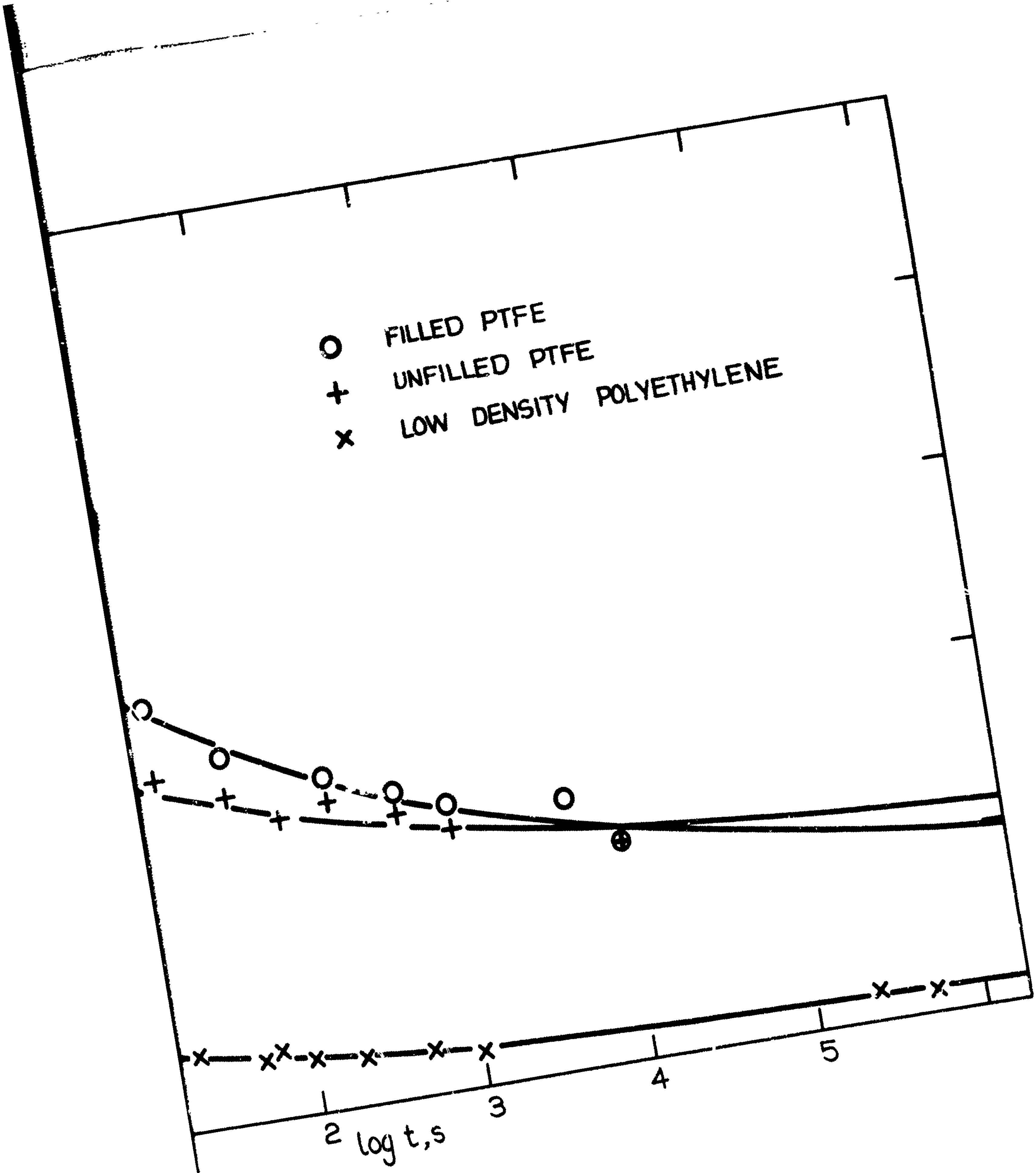


FIG. 2 COMPARATIVE STRESS RELAXATION DATA



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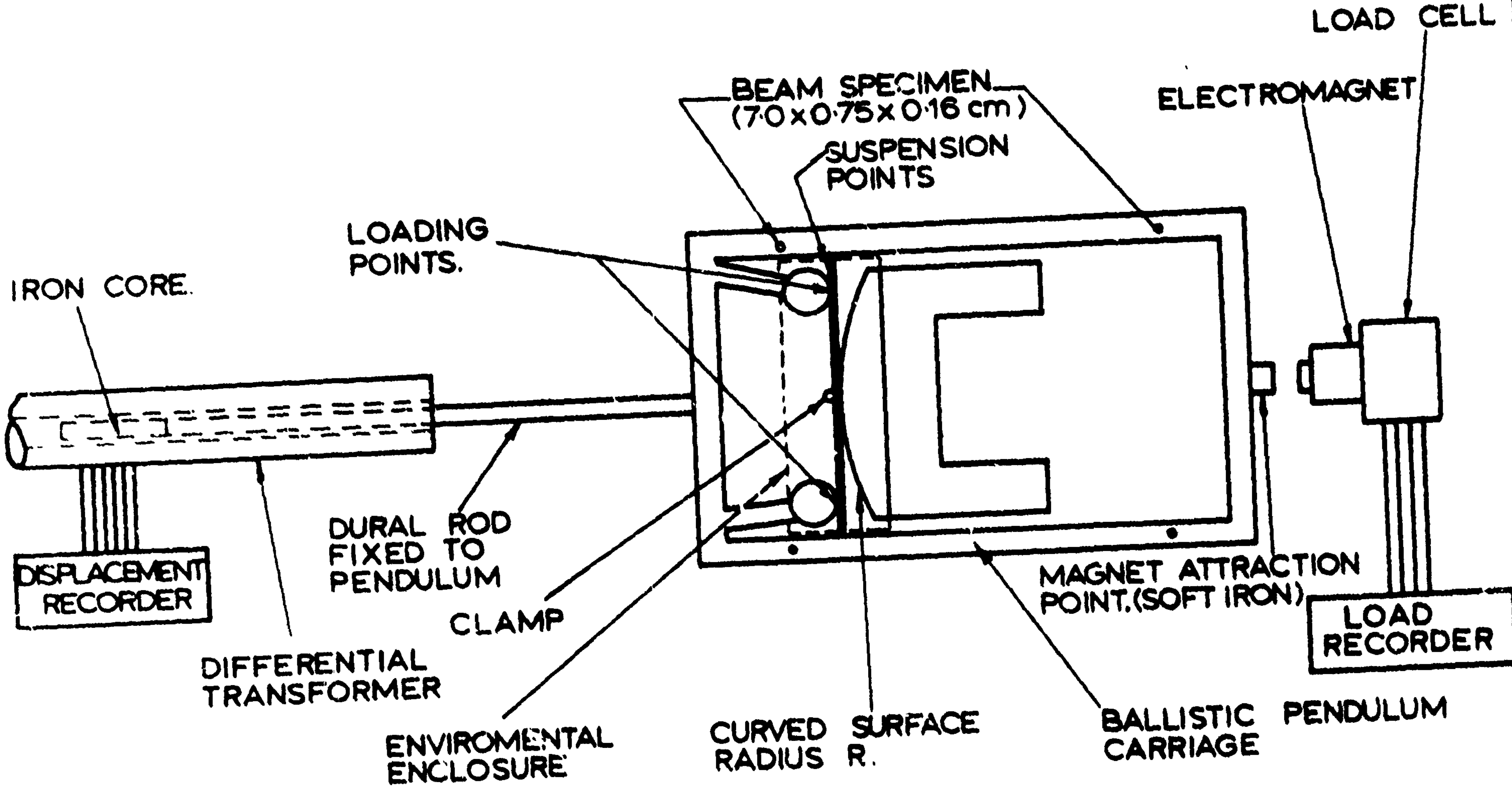

FIG 1 FLEXURAL STRESS RELAXATION APPARATUS